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CLINICAL STUDIES ON THE NUTRITIONAL EFFECTS OF INTRAVENOUS ADMINISTRATION OF FAT EMULSION

by

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I. INTRODUCTION

Surgeons have frequently noted that the nutritional status of their surgical patients greatly influences the results of their surgical operations. Nevertheless this important fact is still often ignored. Deficiency of nutrition before a surgical operation induces anemia, hypoproteinemia and avitaminosis. Patients in such condition occasionally suffer from complications such as pyrexia and disturbances of function of heart and liver which delay the healing of operative wounds. If indispensable nutriments can not be taken by mouth prior to and after a surgical operation, they must be supplied parenterally. But so far, while all other nutriments (protein, carbohydrate, fluid, electrolytes and vitamins) can be supplied parenterally, fat remains difficult to use parenterally.

In a previous paper published in 1949 from our laboratory, HIKASA[1) 2) 3) 4) 5)] demonstrated that certain emulsions of fat can be given intravenously without any injurious effects. Since then it has been experimentally proved that only triglycerides of unsaturated fatty acids such as oleic and linoleic acid and saturated higher fatty acids such as stearic, palmitic and myristic acid may be used as the components of fat emulsion for the above purpose. Assuming that the sesame oil is most suitable among the natural fats, a well stabilized sesame oil emulsion has been prepared. In our experiments, it became evident that intravenous administration of this fat emulsion into animals under low diet feeding with hypoproteinemia results in a marked economization of protein and depót fat, and the preservation of body weight. The nutritional effects of fat emulsion were obviously confirmed.

The following chapters deal with the clinical side of this problem with particular emphasis on the protein metabolism. They further discuss the catabolic process of fat metabolism.[2)]

II. MATERIALS AND METHODS

1. *MATERIALS*

(1) *Fat Emulsion*

20% sesame oil emulsion was usually used. As this preparation is a sort of colloid solution, a preventive measure for colloid shock must be taken at the time of initial infusion.[2) 22)] With this in-view, the author followed Tatsumi's method.

(2) *Amino Acid Solution*

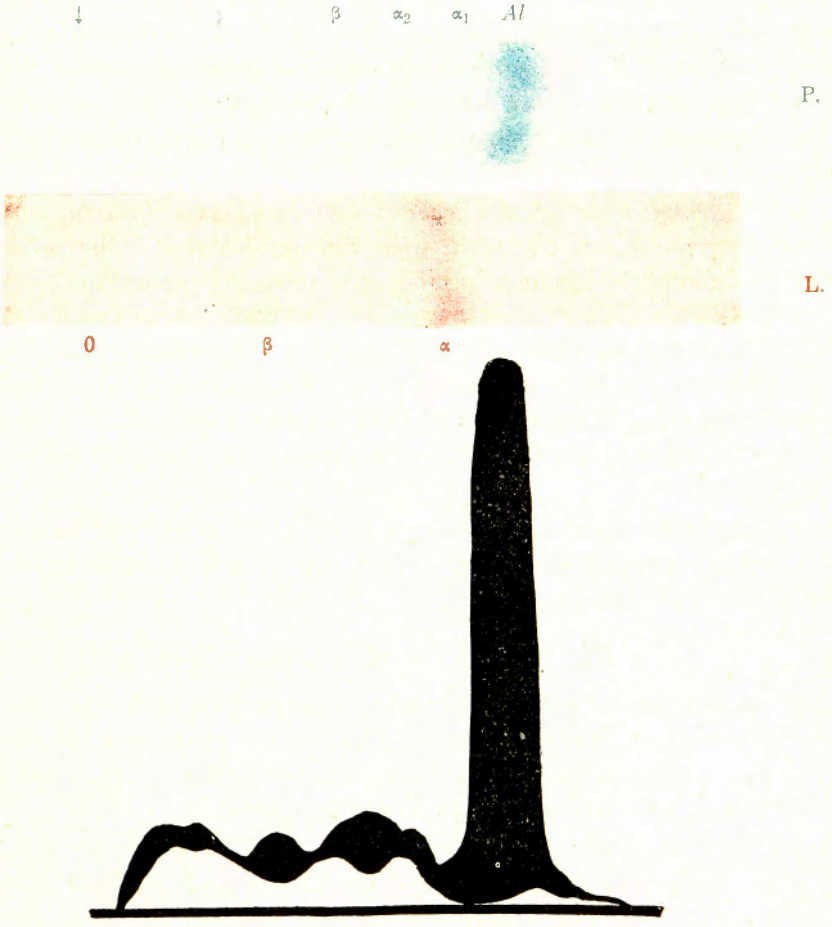
At the outset of these experiments, a 5% solution of polytamin (decomposition product of casein of milk by enzyme) and a 5% solution of preamin (decomposition product of cattle's blood by mineral acids) were infused intravenously twice a day, in the morning and evening. But with these preparations, the occurrence of side effects such as pyrexia, vomiting etc.[19] (especially after the surgical operation) was fairly frequent. Consequently, in cases of simultaneous infusion of fat emulsion with amino acid solution, moriamin-S solution (solution of crystalline synthetic amino acids) was used in its place, and the harmful side effects[19] were reduced. This preparation contains 9.2% of essential amino acids.

2. *EXPERIMENTAL METHODS*

(1) *Determination of the Quantities of Nitrogen and Creatinine in Urine.*

Urinalysis was performed at 6 o'clock every morning. Nitrogen in the urine excreted during 24 hours was determined by KJELDAHL'S[6) 7) 20) 33)] method, and creatinine was determined by YAFFE'S[40)] method.

Fig. 1 The electrophoregram of serum protein and serum lipoprotein in healthy adult.



(2) *Concentration of Serum Protein.*

Blood samples were collected early in the morning before a meal, and the concentration of serum protein was estimated by means of HITACHI's Refractometer.

(3) *Determination of the Electrophoretic Fractions of Serum Protein.*

Blood samples were collected early in the morning before a meal. In the present studies, a veronal buffer of pH. 8.6 and ionic strength 0.1μ was used. After a dialysis of 24 hours, electrophoresis of serum was continued for an hour by the use of Tiselius apparatus[48)49)] (HITACHI's H. T.-B type). Electrophoretic fractions of serum protein were estimated in ascendent leg of the electrophoregram.

(4) *Total Circulatory Serum Volume.*

The determination of total circulatory serum volume was made electrophotometrically by the use of 0.3% EVANS-Blue.[16)]

(5) *Determination of the Quantities of Lipoprotein in Serum.*

The paper electrophoresis of serum was continued for 12 hours, using KOBAYASHI's paper electrophoretic apparatus (horizontal type, Toyo filter paper No. 51, current 0.2 mA per cm and voltage 130 V at 40°C). A veronal buffer of pH. 8.6 and ionic strength 0.05μ was used. Protein was marked on a strip with Amidoschwarz 10 B, and lipid on another with Oil red O,[39)37)] and the protein and lipid on these strips were estimated directly with densitometer of electrophotocells. Electrophoretic fractions of lipoprotein in serum were sorted according to the method asserted by ELAINE and BOSSACK.[37)] Electrophoregram of the serum lipoprotein of a healthy adult is shown in Fig. 1.

(6) *Determination of the Properties of the Tissue Protein.*

The tissue protein was extracted with the physiological saline solution, and the ratio of saline soluble to insoluble protein was measured according to FISHMAN and VEEN's method.[8)9)]

(7) *Rough Estimation of the Properties of the Water-Soluble Lipid (Probably, a Protein Combination) Contained in Organs.*

In this estimation, KUNKEL's[38)] turbidity method was used.

(8) *Determination of Organic Phosphorus in Phospholipids Contained in Organs.*

By the use of FAWAZ-LIEB-ZACHERL's method,[23)23)] after the removal of water soluble inorganic phosphorus by extraction, the amount of organic phosphorus in phospholipids was measured.

III. RESULTS AND DISCUSSION

In the present studies, we have excluded patients with perforation of the stomach, extreme disturbance of liver function and high degree of anemia. Patients of similar body conditions were selected for the clinical examination. The anesthesia for the surgical operation was also limited to local anesthesia.

(1) *Electrophoretic Fractions of Serum Protein and Paper Electrophoregram of Serum Lipoprotein in Healthy Adults and Patients Suffering from Gastric Ulcer and Cancer.*

As seen in Table 1,[31] the patients suffering from gastric cancer[54] and ulcer exhibited a decrease of albumin fraction and serum protein concentration, compared with healthy adults. Thus, a decrease of α- and β-lipoprotein, and an increase of

Table 1 Serum protein of healthy adults and patients suffering, gastric ulcer and cancer. (Electrophoretic fractions)

Diagnosis	Conc. of serum protein (g/dl)	Electrophoretic fraction of protein (%)			
		Alb.	α-Glob.	β-Glob.	γ-Glob.
Healthy adult	7.4	59.34	9.71	13.52	18.69
Gastric cancer	6.4	49.51	9.08	16.21	25.10
Gastric ulcer	6.7	53.80	9.35	14.79	21.13

O-lipoprotein in serum were observed in cases of patients suffering from gastric cancer and ulcer (Table 2).

Table 2 Serum lipoprotein of healthy adults and patients suffering gastric ulcer and cancer. (Paper electrophoretic fractions)

Diagnosis	Paper electrophoretic fractions of lipoprotein (%)		
	α-lipoprotein	β-lipoprotein	*O*-lipoprotein
Healthy adult	31.6	46.2	22.3
Gastric cancer	22.5	39.7	37.3
Gastric ulcer	28.4	39.7	32.4

The above results may indicate that, though the storage fat was mobilized into the blood, the subsequent oxidation of mobilized fat was not smoothly carried on. This may be explained by the deficiency of glycogen and vitamins in the body.

(2) *Changes in Serum Protein Fractions and Paper Electrophoregram of Serum Lipoprotein Following Simple Infusion of Sesame Oil Emulsion.*

When a mixture of 50cc of 20% sesame oil emulsion, 40cc of 20% glucose solution, 10mg of vitamin B_1, 10mg of vitamin B_2 and 100mg of vitamin C was infused intravenously into the patients suffering from gastric ulcer, the serum protein concentration slightly increased with the lapse of time, and at the same time an apparent change in serum protein fractions could be observed. In other words, the increase of γ-globulin fraction in serum protein was observed during one hour after the injection, while α- and β-globulin fractions kept increasing from half an hour to 3 hours after the injection (Table 3).

In a paper previously published in 1950, Oncley, Gofman[36] and others asserted that the most part of plasma lipid is combined with protein to form lipoprotein, and exists in the form of α- or β-globulin fraction. Furthermore, in 1954, Elaine, Bossack[37)39)] and others demonstrated that α-lipoprotein is contained in albumin and α_1-globulin, that β-lipoprotein is contained in α_2-, β_1- and β_2-globulin of serum protein, and that α-lipoprotein contains cholesterol at the rate of 5 per cent and phospholipid at the rate of 45~50 per cent and β-lipoprotein contains cholesterol at the rate of 40 per cent and phospholipid at the rate of 35 per cent.

Table 3 Changes of electrophoretic fraction of serum protein following single infusion of sesame oil emulsion into patients suffering from gastric ulcer.
(Each values show means of 3 samples)

Intervals after injection	Conc. of serum protein (g/dl)	Electrophretic fraction of serum protein (%)			
		Alb.	α-Glob.	β-Glob.	γ-Glob.
Before	6.5	57.14	5.01	14.76	24.36
30 min. after injection	6.8	54.49	5.10	15.21	26.47
1 hour after injection	6.8	51.26	7.61	17.36	25.01
3 hours after injection	7.1	56.14	7.21	12.24	24.71
6 hours after injection	7.0	60.21	6.18	10.34	23.47
12 hours after injection	6.4	58.04	3.91	14.57	24.09

The other lipids are present in the γ-globulin fraction in the form of *O*-lipoprotein. By the intravenous administration of sesame oil emulsion, the infused fat globules are phagocytized by the reticuloendothelial cells in the lung, liver and spleen. After being changed to phospholipids from glycerides in these cells, they are discharged back into the blood stream. Then the α- and β-globulin fractions in serum show a marked increase in parallel with the obvious increase of α- and β-lipoprotein (Table 4).

Table 4 Changes in paper electrophoretic fractions of serum lipoprotein of patients suffering gastric ulcer following single infusion of fat emulsion.
(Each values show means of 3 samples)

Intervals after injection	Increase of paper electrophoretic fractions of serum lipoprotein (%)				Co-R. of serum	Cd-R. of serum
	α-lipoprotein	β-lipoprotein	0-lipoprotein	β+0/α		
Before	—	—	—	2.0	R_2	R_6
30 min. after injection	+20	+14	+20	1.9	R_1	R_{12}
1 hour after injection	+50	+30	+18	2.1	R_1	R_8
3 hours after injection	− 7	+ 6	− 5	2.3	R_2	R_6
6 hours after injection	−15	− 4	−13	2.2	R_2	R_8
12 hours after injection	± 0	−10	−10	1.8	R_2	R_6

(3) *Change in Various Tissue Proteins Following Simple Infusion of Sesame Oil Emulsion.*

A mixture of 50cc of fat emulsion, 40cc of glucose solution, 10mg of vitamin B_1, 10mg of vitamin B_2 and 100mg of vitamin C was infused intravenously into surgical patients before laparotomy. Pieces of the liver and muscle were resected, and their tissue protein was estimated at regular intervals after intravenous infusion. α- and β-lipoprotein and α- and β-globulin in serum began to decrease after 3 hours or more, while, on the other hand, with the increase of the saline soluble protein contents in the liver. The ratio of saline soluble to insoluble protein rose, and α+

Table 5 Changes in tissue protein of the liver of patients suffering gastric ulcer following single administration of fat emulsion.
(Each values show means of 5 samples)

Intervals after injection	Kunkel unit		Ratio of soluble/insoluble protein	Electrophoretic fraction of serum protein (g%)			
	Serum	Liver		Alb.	α-Glob.	β-Glob.	γ-Glob.
Before	24	9.3	0.84	4.05	1.77	0.94	3.17
3 hours after injection	39	15.0	1.34	5.67	2.14	1.45	2.63
6 hours after injection	21	8.3	1.04	5.38	1.57	1.27	3.81
12 hours after injection	26	9.3	0.89	6.01	1.46	0.95	2.59

β-globulin fractions in liver protein always increased at the same time. It has also been observed that the above changes are usually accompanied with a parallel increment of water soluble lipid in the liver.

Further studies on the above were made. The amount of 2.0g of fat emulsion per kg of body weight was infused intravenously into rats. They were sacrificed by bleeding at definite intervals without anesthesia after the infusion. Their liver, muscles and kidneys were extirpated and the phospholipid and tissue protein contents of these organs were determined. The saline soluble protein content had obviously increased in all of these organs in accordance with the increase of the tissue protein content. A parallel increase of α- and β-globulin in tissue protein was also evident (Figs. 2, 3, 4 and Table 6).

Consequently, it is possible to assume that the intravenously infused fat is phagocytized by the reticuloendothelial cells in the lung, liver and spleen,[44) 24)] and after being changed into phospholipid from glyceride, it is again discharged into the blood stream. Then phospholipid is transformed to lipoprotein, which is

Fig. 2 Changes of phospholipid content and (α+β)-globulin fractions in the muscles following single administration of fat emulsion

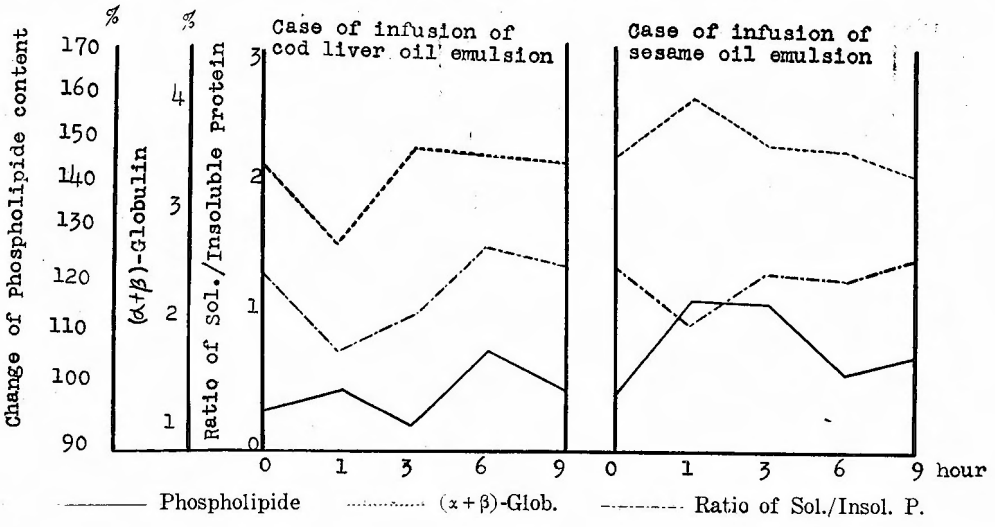


Fig. 3 Changes of phospholipid content and (α+β)-globulin fractions in the liver following single administration of fat emulsion.

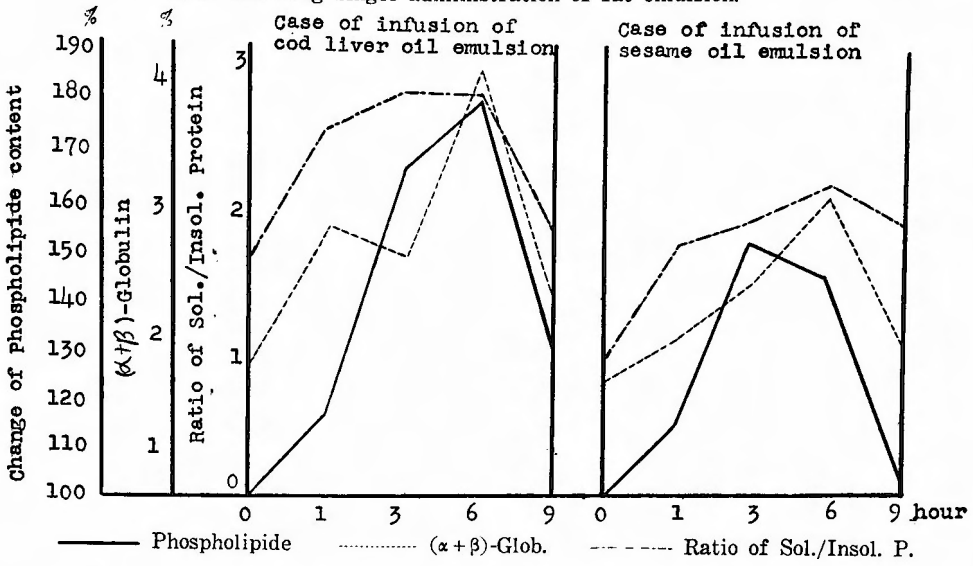
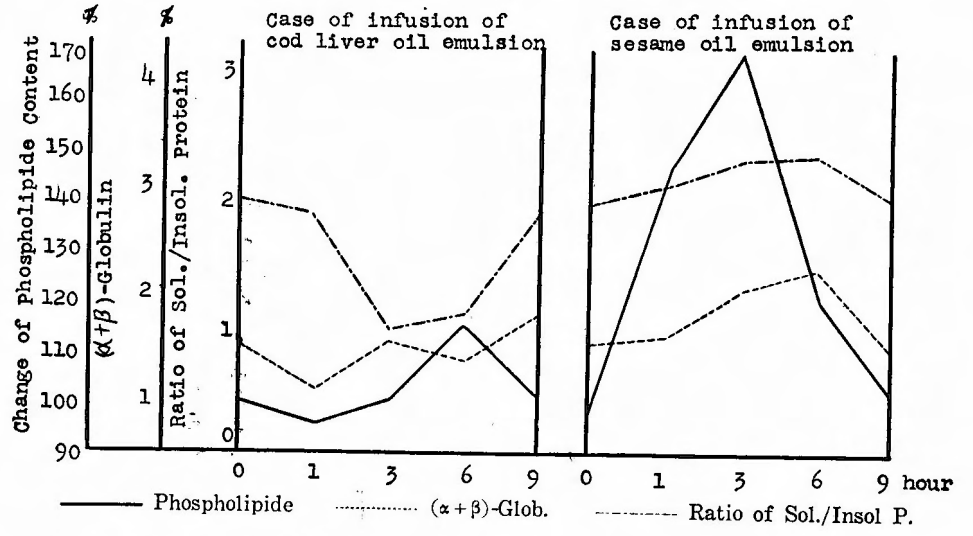


Fig. 4 Changes of phospholipid content and (α+β)-globulin fractions in the kidneys following single administration of fat emulsion.



the combined form of phospholipid. This is transfered to hepatic parenchymatous cells and further to extrahepatic tissues. In other words, the phospholipid changed from glyceride can not be transfered to these organs in the free form.[43]

Izukura and Shirotani[26) 25)] in our laboratory have clarified the metabolic process of fat globules in artificial emulsion and fatty chyle in vivo by means of histochemical examination. In these experiments, the phospholipids which were produced from glycerides in the alveolar phagocytes, Kupffer's cells and splenic reticuloendothelial cells were well stained by Baker's method, which is specific for the staining of phospholipid. The phospholipids in the hepatic parenchymatous cells

Table 6 Changes in tissue protein of the liver and the kidney of rats following single adminisration of fat emulsion.

Intervals after injection	Tissue protein (g%)		Ratio of solub./insol. protein	
	Liver	Kidney	Liver	Kidney
Before	17.12	8.81	1.41	2.07
1 hour after injection	17.75	9.81	1.71	2.15
3 hours after injection	18.18	9.98	1.82	2.19
6 hours after injection	17.93	10.26	1.95	2.26
9 hours after injection	17.46	8.63	1.88	2.03

could be stained only by SMITH-DIETRICH'S and CIACCIO'S methods, which are not specific for the staining of phospholipid in a narrow sense.

These findings also suggested that the phospholipids which were produced from the infused fats were transfered to the hepatic parenchymatous cells or extrahepatic tissues in the form of lipoprotein, not in the free form.

In a previous paper, SHIROTANI, ASADA[32] and IZUKURA in our laboratory demonstrated the following facts by means of histochemical examinations. Lower fatty acids and highly unsaturated fatty acids are chiefly transfered into the hepatic parenchymatous cells and metabolized there. On the other hand, higher fatty acids except highly unsaturated fatty acids, such as myristic, palmitic, stearic, oleic and linoleic acid, are transfered not only into the hepatic parenchymatous cells but also into the extrahepatic tissues directly and metabolized smoothly.[24) 31)] In the present experiment, a further investigation of this problem was made biochemically. An emulsion of cod liver oil containing highly unsaturated fatty acids in large quantity and a sesame oil emulsion which consists of higher fatty acids except highly unsaturated fatty acids were respectively infused intravenously into rats at the rate of 2.0g per kg of the body weight. Instantly, the changes of phospholipid contents and of α- and β-globulin in the tissue protein were examined.

As shown in Figs. 2, 3 and 4, the administration of the sesame oil emulsion caused an increase of the phospholipid contents and α- and β-globulin of saline soluble tissue protein not only in the hepatic parenchymatous cells but also in the extrahepatic tissues (kidneys and muscles). But, by the administration of cod liver oil emulsion, they increased to a perceptible extent only in the hepatic parenchymatous cells and their increase in the extrahepatic tissues was comparatively slight. In the above experiment, it was demonstrated that higher fatty acids are directly transfered not only into the hepatic parenchymatous cells but also into the extrahepatic tissues after being changed to lipoprotein, and are metabolized in these tissues. Highly unsaturated fatty acids and lower fatty acids are transported only into the hepatic parenchymatous cells in the form of lipoprotein and metabolized there. The agreement of our results of present biochemical studies with those of the recent histochemical experiments leads to the following conclusion. Fat globules are phagocytized by the reticuloendothelial cells in the lung, liver and spleen when the sesame

oil emulsion is infused intravenously into humans and animals. They are transformed into phospholipids from glycerides in these cells, and afterward are again discharged into the blood stream. They are changed to lipoprotein in the blood stream, and are transfered into the hepatic parenchymatous cells and into the extrahepatic tissues. As demonstrated by HASHINO[21] in our laboratory, if proper quantities of glucose and various vitamins necessary in the fat metabolism are used, fatty acids which have been transported into these organs in the form of lipoprotein can enter into the KREBS's T. C. A. Cycle by way of Fatty Acid Cycle (after LYNEN). At the end, they are oxidized to carbon dioxide and water. The important problem, however, is whether the obvious nutritional effects of sesame oil emulsion obtained with animals by OSA[20) 33)] in our laboratory can also be well observed in the human body. We have carried out various clinical experiments for the purpose of clarifying this problem.

(4) *Clinical Examination on the Nutritional Effects of Sesame Oil Emulsion.*

(i) *In the Case of Administrations prior to and after Surgical Operation.*

From the patients who had been suffering from gastric cancer or ulcer, we selected the cases with similar serum protein concentration, serum electrophoregram and total circulatory serum volume. In making this selection, similarity was also noted in regard to the caloric intake, the nitrogen balance, the degree of bleeding at the operation, and, the age and the body weight. Various examinations were then performed upon these patients (Table 7). They were first divided into three

Table 7 Condition in the objects for present clinical investigation.

Disease	Group	Volume of Bleeding (cc)	Duration of Operation (minutes)	Serum Protein at Entrance				
				Conc. of Serum Protein (g/dl)	Electrophoretic Fraction (%)			
					Alb.	α-glob.	β-glob.	γ-glob.
Gastric Ulcer Cases	Fat Group	472	225	6.4	47.44	7.74	15.43	18.52
	Amino Acid Group	409	200	6.3	46.44	5.39	16.72	20.17
	Control	466	220	6.7	46.98	6.82	14.79	21.13
Gastric Cancer Cases	Fat Group	386	156	6.9	48.02	5.78	11.74	25.34
	Amino Acid Group	360	168	6.6	48.22	5.80	12.08	23.39
	Control	390	169	6.4	49.51	7.61	13.21	20.59

(Mean value)

Table 8 Total of patients who underwent the gastrectomy.
(Various examinations were performed in these patients.)

Diagnosis	Fat group	Amino acid group	Control	Summary
Gastric ulcer cases	7	5	6	18
Gastric cancer cases	11	9	10	30
Summary	18	14	16	48

Table 9 Changes of daily input of Proteim by oral administration of nutritional supplments and bloodtransfusion after gastrectomy.
(Standard values in our experiments)

Days after operation	Gastric ulcer cases	Gastric cancer cases
1	15.0	15.0
2	3.8	3.8
3	3.8	3.8
4	6.5	5.0
5	11.0	7.5
6	18.0	13.5
7	33.0	16.0
8	35.0	17.0
9	46.0	20.0
10	51.0	21.0
11	57.0	35.0
12	59.0	40.0
13～15	60.0～65.0	55.0～65.0

(g/day)

Table 10 Nutritional effects of sesame oil emulsion to surgical patients before and after gastrectomy.
(Gastric cancer cases)

Group	Days of examination	Serum protein: Conc. of serum protein (g/dl)	Electrophoretic fraction (%): Alb.	α_1-glob.	α_2-glob.	β-glob.	γ-glob.	Ratio A/G	Circulatory serum protein (g)	Nitrogen balance (g) ((-)negative (summay)	Change of body weight (%)
Fat Group	Befor	7.3	48.63	6.91	7.96	13.01	23.49	0.946	168	–	–
	After 5 days	7.8	45.24	6.21	9.91	15.49	23.16	0.826	159	−34.3	−5.4
	After 10 days	7.0	48.25	5.32	8.84	14.94	22.65	0.933	186	−18.8	−2.6
	After 15 days	6.9	51.52	4.61	6.88	13.48	23.82	1.021	162	(−53.1)	−2.9
Amino Acid Group	Before	7.0	45.14	6.29	7.41	13.49	26.67	0.823	163	–	–
	After 5 days	7.5	43.96	8.49	7.64	12.47	27.86	0.784	130	−60.1	−7.1
	After 10 days	6.3	45.64	8.32	8.24	12.94	27.86	0.834	151	−26.1	−5.9
	After 15 days	7.0	45.12	9.04	8.94	13.41	23.49	0.822	157	(−86.2)	−5.8
Control	Before	7.2	46.24	6.41	11.41	12.36	23.57	0.860	151	–	–
	After 5 days	7.9	43.14	6.49	11.49	15.41	24.47	0.759	127	−70.4	−6.7
	After 10 days	6.7	45.11	7.49	10.17	12.41	24.82	0.822	133	−26.2	−5.3
	After 15 days	6.7	46.12	6.41	9.32	13.96	24.19	0.856	150	(−96.6)	−5.7

(Mean value)

Table 11 Nutritional effects of sesame oil emulsion to surgical patients before and after gastrectomy.
(Gastric ulcer cases)

Group	Days of examination	Serum protein: Conc. of serum protein (g/dl)	Electrophoretic fraction (%): Alb.	α_1-glob.	α_2-glob.	β-glob.	γ-glob.	Ratio A/G	Circulatory serum protein (g)	Nitrogen balance (g) {( )negative} {summary}	Change of body weight (%)
Fat Group	Befor	7.4	51.49	4.71	9.32	15.07	19.41	1.061	161	–	–
	After 5 days	7.9	47.21	3.96	9.72	16.24	22.87	0.894	145	−41.4	−6.6
	After 10 days	6.8	50.76	5.72	7.42	15.96	20.14	1.031	149	− 2.3	−4.7
	After 15 days	6.9	51.94	4.72	6.92	14.76	21.66	1.081	160	(−43.7)	−4.7
Amino Acid Group	Befor	7.5	55.12	4.39	7.04	15.01	18.44	1.239	159	–	–
	After 5 days	7.9	46.41	5.01	9.86	16.96	21.76	0.865	140	−58.0	−6.9
	After 10 days	7.0	49.53	6.21	7.04	17.01	20.21	0.981	148	−42.0	−7.0
	After 15 days	6.7	49.51	7.01	8.41	15.32	19.71	0.979	161	(−100.0)	−6.3
Control	Before	7.3	53.49	3.91	7.01	15.97	19.66	1.148	164	–	–
	After 5 days	8.0	46.34	7.96	8.24	16.32	21.14	0.864	142	−52.8	−6.8
	After 10 days	7.0	46.86	8.76	9.22	16.49	17.69	0.882	150	−43.1	−7.3
	After 15 days	6.9	49.37	7.94	8.02	14.98	19.69	0.975	159	(−95.9)	−6.4

(Mean value)

groups. A mixture of 50cc of 20% sesame oil emulsion, 40cc of 20% glucose solution, 10mg each of vitamin B_1 and B_2 and 100mg of vitamin C, was given to the fat group twice a day, in the morning and evening. Likewise, a mixture of 50cc of 5% amino acid solution, 40cc of 20% glucose solution, 10mg each of vitamin B_1 and B_2 and 100 mg of vitamin C, was given to the amino acid group, 40cc of 20% glucose solution, 10mg each of vitamin B_1 and B_2 and 100mg of vitamin C, were given to the control group twice a day. The above procedure was repeated everyday for 5 days prior to the surgical operation and for 10 days after it. To each of these groups constant quantities of blood, 5% glucose solution and RINGER's solution were administered over the same period of time intravenously or subcutaneously.

Throughout the present examination, the daily nitrogen input and caloric intake due to the oral administration of nutritional supplement, bloodtransfusion and subcutaneous infusion were made uniform. The nutritional effects of sesame oil emulsion were examined by means of daily estimations and comparisons of the urinary creatinine excretion, the nitrogen balance, the serum protein concentration, the electrophoretic pattern, the ratio of albumin to globulin in serum and the total circulating serum volume, concerning each of the fat, the amino acid or the

control groups.

In the gastric cancer cases, the nitrogen loss in the fat group after the surgical operation was reduced to the half of that in the control group, and the nitrogen balance returned to normal at an earlier period of time than the control group. Even with the administration of 5% amino acid solution, more desirable results than those of the control group were obtained, but they were not to be compared with the results produced by the administration of the fat emulsion (Figs. 5, 6 and 7). The nutritional effects of the fat emulsion were also observed in the gastric

Fig. 5 Changes in nitrogen balance before and after gastrectomy.
(Control group of gastric cancer cases)

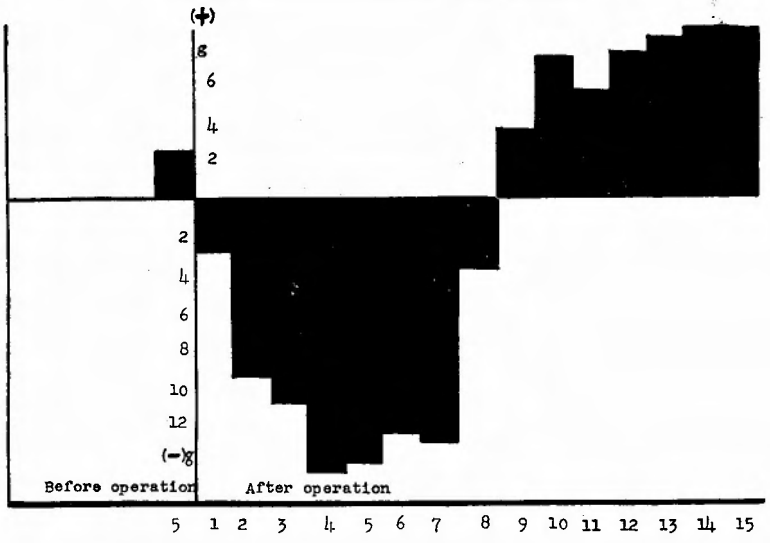


Fig. 6 Changes in nitrogen balance before and after gastrectomy.
(Amino acid group of gastric cancer cases)

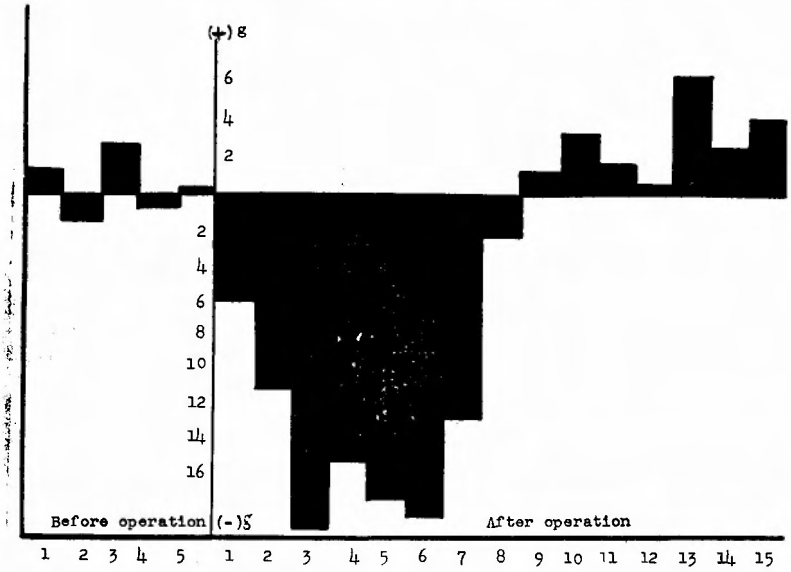
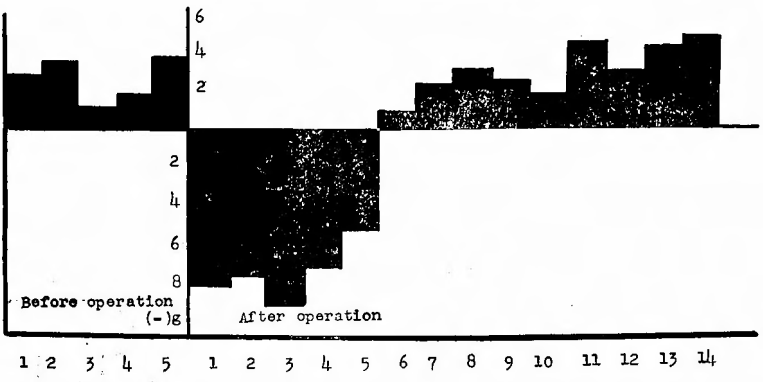


Fig. 7 Changes in nitrogen balance before and after gastrectomy.
(Fat group of gastric cancer cases)



ulcer cases (Figs. 8 and 9). The consumption of protein was reduced to the minimum by the administration of the fat emulsion. The recovery of electrophoregram of serum protein was made earlier in the patients who had the infusion of the fat emulsion as compared with other patients (Tables 10 and 11). When the fat emulsion was infused into the patients suffering from gastric cancer or ulcer, the electrophoretic pattern became normal 10 days after the surgical operation. In the control group, it became normal 15 days after the surgical operation in the gastric ulcer cases, but in the gastric cancer cases, it did not become normal even after 15 days.

Fig. 8 Changes in nitrogen balance before and after gastrectomy.
(Control group of gastric ulcer cases)

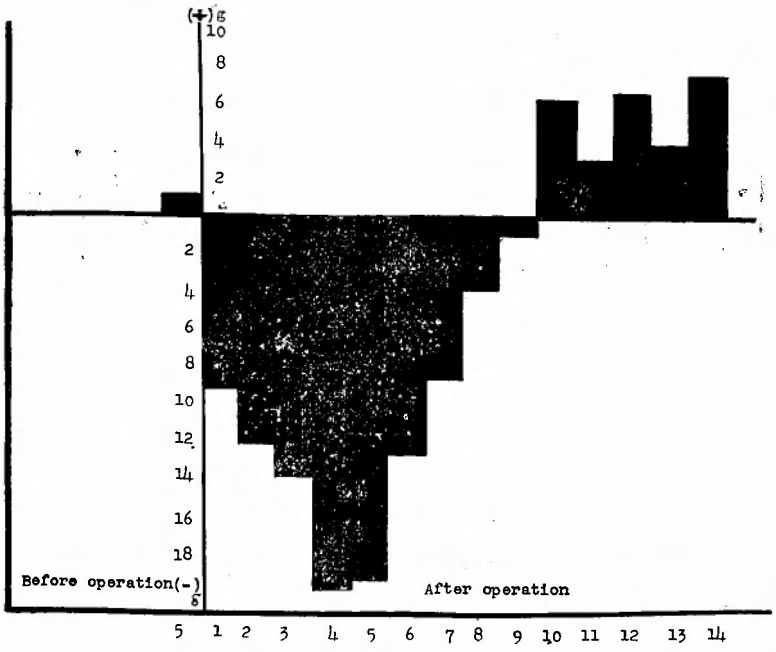


Fig. 9 Changes in nitrogen balance before and after gastrectomy.
(Fat group of gastric ulcer cases)

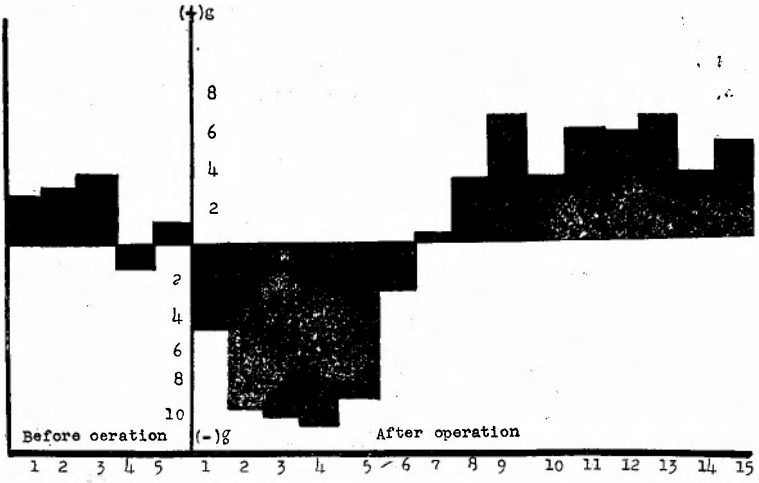
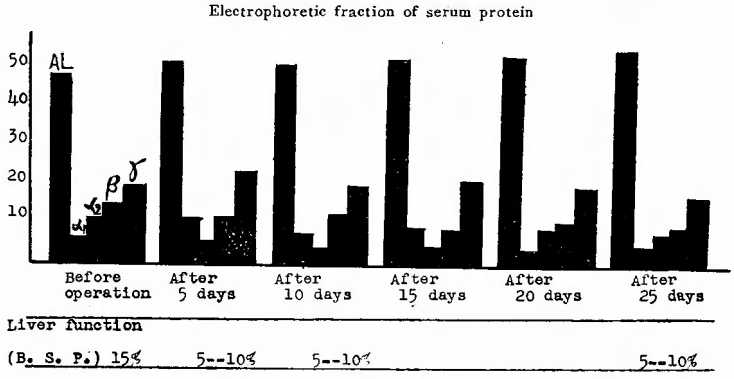
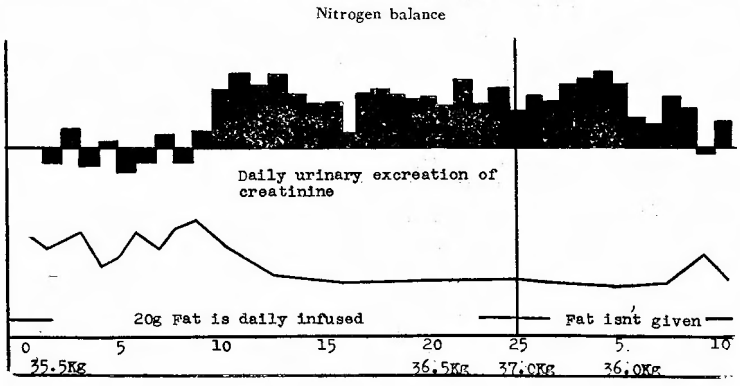


Fig. 10 Nutritional effects of sesame oil emulsion in a case of esophageal stenosis.

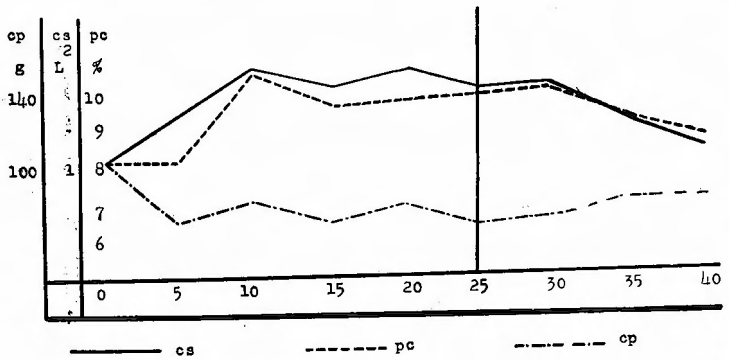
A. Electrophoretic fraction of serum protein and liver function (Hepatosulphalein-test).



B. Changes in nitrogen balance and urinary creatinine excretion.



C. Changes in circulatory serum volume, concentration of serum protein and total circulatory serum protein.



Circulatory serum volume……cs
Serum protein concentration……pc
Circulatory total serum protein……cp

Table 12 Changes of paper electrophoretic fraction of serum lipoprotein after gastrectomy.
(Gastric ulcer cases)

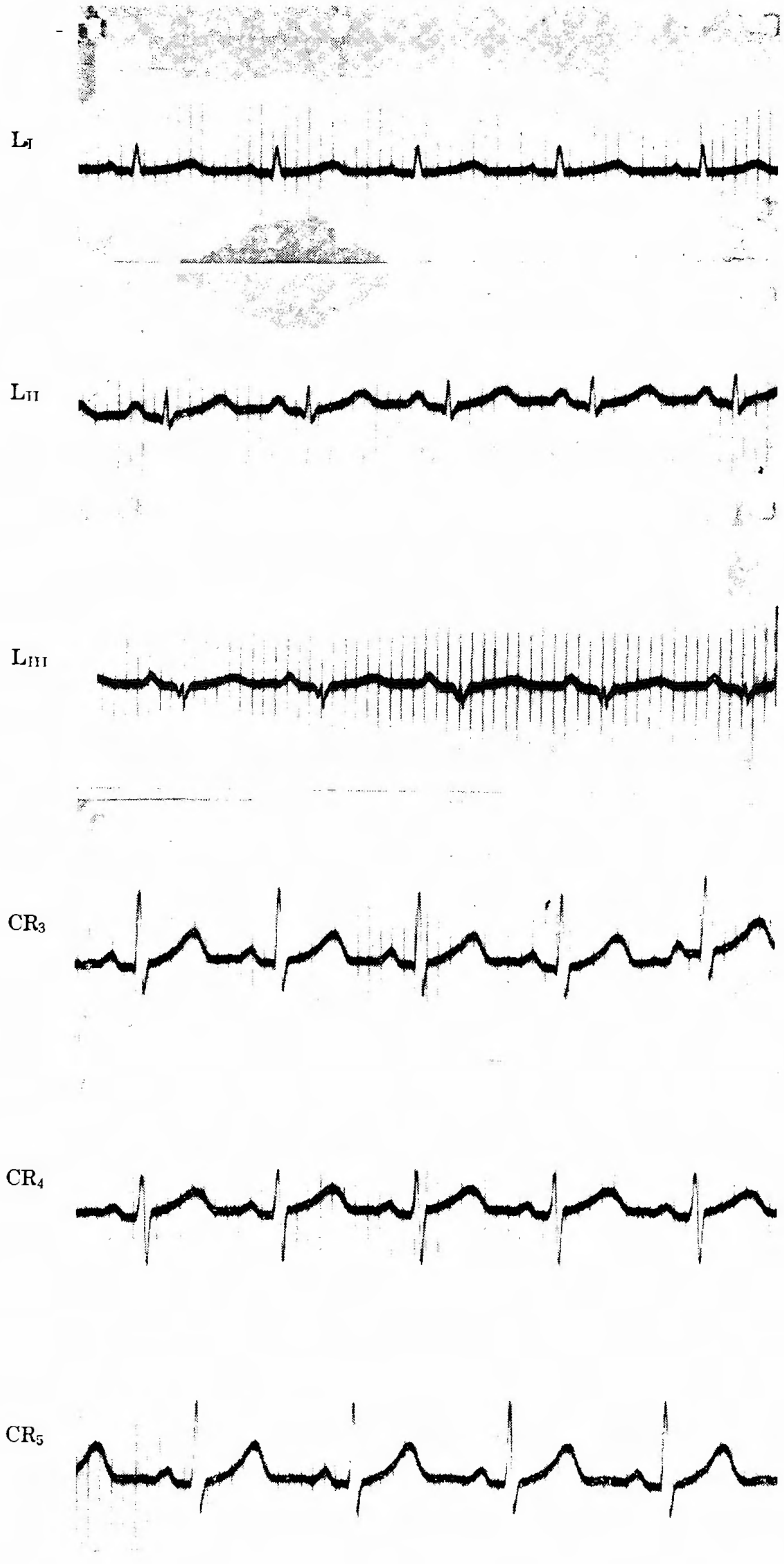
Days after operation	Changes of paper electrophoretic fraction of serum lipoprotein (%)		
	α-lipoprotein	β-lipoprotein	*o*-lipoprotein
Before	——	——	——
2	−13	−29	− 7
3	+20	+40	− 6
5	+31	+48	+10
7	−11	+10	− 5
10	+20	−21	+ 3
15	+20	−12	+ 6

(Mean value)

Table 13 Nutritional effects of simultaneous infusion of sesame oil emulsion with amino acid solution.
(Each values show means of 3 samples)

Days after operation	Control			Fat Group			Fat + Amino Acid Group		
	Nitrogen balance (g)	γ-glob. of serum protein(%)	Ratio A/G	Nitrogen balance (g)	γ-glob. of serum protein (%)	Ratio A/G	Nitrogen balance (g)	γ-glob. of serum protein (%)	Ratio A/G
Before	−	19.66	1.148	−	19.4	1.061	−	21.3	1.041
5th day after operation	−52.8	21.14	0.864	−41.4	22.9	0.894	−37.2	24.7	0.872
10th day after operation	−43.1	17.69	0.882	− 2.3	20.1	1.031	− 3.2	21.4	0.942
15th day after operation	Summary: (−95.9)	19.69	0.975	Summary: (−43.7)	21.7	1.081	Summary: (−40.4)	20.7	1.048

Fig. 11 Electrocardiogram in a case of esophageal stenosis at the end of repeated infusions of sesame oil emulsion over fairly long period.



Thus, the intravenous administration of fat emulsion prevented the decrease of body weight and achieved a remarkable economization of protein. Furthermore, there is no apparent danger of lipemia due to the intravenous administration of fat emulsion (Table 12). Estimation of lipoprotein in the serum revealed no troublesome tendency of stagnation of serum lipid. Next we performed a simultaneous administration of fat emulsion with amino acid solution and glucose solution into three cases who underwent the gastrectomy due to gastric ulcer (not included among the cases shown in Table 8). We infused a mixture of 40cc of 20% sesame oil emulsion, 50cc of moriamin-S solution, 40cc of 20% glucose solution, 10mg of vitamin B_1, 10mg of vitamin B_2 and 100mg of vitamin C, twice a day, in the morning and evening, for 5 days before gastrectomy and for 10 days after it.

In the patients who had the simultaneous administration of the fat emulsion with amino acid solution, we could not observe a greater economization of protein as measured by the nitrogen balance (Table 13). However, a more remarkable and rapid improvement of electrophoregram was observed in the case of simultaneous infusion. Accordingly, it may be concluded that if an amino acid solution is administered intravenously with the fat emulsion, more remarkable nutritional effects can be obtained (Table 14).

Table 14 Nutritional effects of simultaneous infusion of fat emulsion with amino acid solution into patients with abnormal electrophoregram of serum protein before surgical operation.
(Gastric ulcer case, 41 years old, ♂)

Days after operation	Serum protein					
	Conc. of protein (g/dl)	Electrophoretic fraction (%)				A/G
		Alb.	α-Glob.	β-Glob.	γ-Glob.	
Before	7.0	42.56	2.14	5.74	34.62	0.741
5th day after operation	7.2	42.24	5.09	9.41	28.73	0.732
10th day after operation	6.9	44.82	13.12	12.36	28.70	0.791
15th day after operation	7.0	50.01	10.43	15.24	24.31	1.003

(ii) *Nutritional Effects of Fat Emulsion to Extremely Under-Nourished Patients.*

Eight under-nourished patients of approximately the same age and body weight with similar serum protein concentration, total circulatory serum volume and electrophoregram of serum protein were selected. Their daily intake of calorie was about 800 Cal and that of protein was 20～25g. We infused them for fifteen days with the daily total of a mixture of 100cc of sesame oil emulsion, 80cc of 20% glucose solution, 20mg each of vitamin B_1 and B_2 and 200mg of vitamin C. The nutritional effects were studied from the viewpoint of protein metabolism. As shown in Table 16, the nitrogen balance gradually became normal instead of negative, and a tendency for a decrease of the urinary nitrogen output was observed. These were followed by the increase of serum protein concentration and albumin fraction and the improvement of the other parameters of the serum protein. Concordantly, the body weight was slightly increased. Thus, the remarkable nutritional effects of sesame oil emul-

Table 15 Changes of the amount of urine after gastrectomy.

Days after operation	Gastric cancer cases (cc)			Gastric ulcer cases (cc)		
	Control	Amino acid group	Fat group	Control	Amino acid group	Fat group
1	397	308	584	400	450	370
2	878	560	966	640	590	740
3	952	817	962	740	740	840
4	816	872	1200	690	470	960
5	1110	618	1042	940	1100	1010
6	1080	1074	1086	1030	1000	1020
7	1096	1064	1078	970	1040	1200
8	1126	1432	1032	1200	1300	1400
9	1086	898	1306	1020	1200	1200
10	1034	848	1164	1070	940	1256

(Mean value)

Table 16 Nutritional effects of sesame oil emulsion to poorly nourished patients.
(Each values show means of 8 patients)

Days of examination	Body weight (kg)	Serum protein						Nitrogen balance (g)	Excretion of creatinine (g)
		conc. of serum protein (g/dl)	Electrophoretic fraction (%)				Ratio		
			Alb.	α-glob.	β-glob.	γ-glob.	A/G		
Before	47.5	7.0	47.24	14.73	10.93	27.10	0.893	——	——
5th day after infusion	47.5	7.1	44.87	14.93	12.63	27.56	0.812	−1.9740	1.1427
10th day after infusion	49.0	7.2	48.48	16.86	11.49	25.17	0.941	+3.4762	1.0521
15th day after infusion	50.5	7.2	51.96	12.28	11.42	24.34	1.085	+6.0421	1.0427
5th day after interruption	50.5	7.0	51.42	11.99	11.36	25.22	1.056	+4.2341	1.1021

sion were also proved in poorly nourished patients. The question remained whether the lipemia might not be increased by the intravenous administration of the fat emulsion in these patients. An estimation of lipoprotein in serum was made in order to clarify the above point. As shown in Table 17, the danger of encouraging lipemia was not important. From the fifth day to the tenth day after the beginning of the administration, α- and β-lipoprotein increased slightly, but on the 15th day, serum lipid fell below its level before infusion, and a tendency of decrease of α- and β-globulin, and, of α- and β-lipoprotein in serum was observed. Accordingly, the improvement of the electrophoregram was also evident. When we were intending to clarify the nutritional effects of fat emulsion on the poorly nourished patient, a representative case was accidentally received in our clinic. The patient had swallowed strong alkali in order to commit suicide and, though prompt measures had prevented death, a marked stenosis of the esophagus had resulted with complete inability to take food by mouth. At first, a jejunal fistula was surgically constructed, and a forced

Table 17 Changes in paper electrophoretic fraction of serum lipoprotein following repeated infusions of sesame oil emulsion into under-nourished patients. (Each values show means of 10 samples)

Days after operation	Serum protein					Changes of serum lipoprotein (%)			
	Conc. of protein (g/dl)	The fraction of protein (%)							
		Alb.	α-glob.	β-glob.	γ-glob.	α-lipoprotein	β-lipoprotein	*O*-lipoprotein	β+0/α
Before	7.0	50.98	11.67	11.71	25.64	——	——	——	2.1
5th day after operation	7.1	50.76	10.91	12.76	25.60	+25	+23	+20	2.0
10th day after operation	7.2	54.46	10.96	10.36	23.27	−10	+10	+20	+2.0
15th day after operation	7.2	60.51	11.61	10.24	17.64	+ 4	−13	−17	2.0
5th day from the end	7.0	60.34	10.33	11.24	18.09	−15	−20	−30	2.0

Table 17′ Changes of nitrogen balance after gastrectomy. (Gastric ulcer cases)

Days \ Case	U. K. 29, ♂	N. M. 47, ♂	T. U. 61, ♀	U. N. 41, ♂
Operation	− 7.42	−10.42	−11.49	−10.41
1	− 8.69	−15.76	−17.79	−19.26
2	−10.42	−11.92	−10.21	− 7.41
3	−11.41	− 9.76	− 9.44	−11.17
4	− 9.42	− 8.42	− 7.49	−10.46
5	−10.26	− 4.79	− 3.26	− 5.72
6	− 6.41	− 3.24	+ 2.11	− 4.11
7	− 3.72	− 4.11	− 1.42	+ 3.41
8	− 4.19	+ 3.69	+ 4.77	+ 4.72
9	+ 2.76	+ 4.21	+ 9.02	+ 2.76

(Mean value)

Remarks: Gastrectomy was performed by the inhalation anesthesia and the intravenous infusion of sesame oil emulsion was performed only after gastrectomy.

feeding of the daily equivalent of 2300 Cal through this opening was attempted in co-operation with the Special Aliment Investigation Laboratory, Kyoto University. However, even after the lapse of three weeks, no sign of improvement of the nutritional condition was observed, perhaps due to some defects in the nature of the nutriment. Then the daily intake of calorie through the jejunal fistula was decreased to 1800 Cal. And a mixture of 50cc of 20% sesame oil emulsion, 40cc of 20% glucose solution, 10mg each of vitamin B_1 and B_2 and 100mg of vitamin C was infused twice a day, in the morning and evening. This procedure was repeated for a month. As shown in Fig. 10, nitrogen balance gradually turned from negative to positive, and so remained. Urinary creatinine excretion, which is an indicator of endogenous protein consumption, was on the decrease. The total circulatory serum volume was restored to the normal and the total circulatory serum protein increased.

The serum protein concentration, which, because of excessive dehydration, was extremely high before the infusion of the fat emulsion, decreased slightly after it. With this increase of the total circulatory serum protein, body weight increased. As to serum protein fractions, contrary to the increase of the albumin fraction, α- and β-globulin decreased after a temporary increase following the beginning of the administration. It is, therefore, plain that even in the case of a prolonged administration of the fat emulsion, there is not the slightest fear of an abnormal increase of serum lipids.[27) 30)] The decrease of γ-globulin fraction, the improvement of the ratio of albumin to globulin in serum and the result of hepatosulphalein-test can not help considering that there is no danger of disturbance of the liver function.[39)] The electrocardiographic study, as shown in Fig. 11, revealed no symptom of the coronal sclerosis. Esophageal cancer is one of the diseases for which surgeons often acutely feel the need of parenteral nutritional supplement.

Esophageal cancer occasionally engenders an intense malnutrition owing to the stoppage of the upper digestive canal at an early stadium of the disease. A mixture of 50cc of 20% sesame oil emulsion, 40cc of 20% glucose solution, 100mg of vitamin C and 10mg each of vitamin B_1 and B_2 was given intravenously into two patients who had been limited the oral administration of nutritional supplements owing to opening of the suture after antethoracic esophagogastrostomy, twice a day, in the morning and evening, over a long period of time. The changes of body weight of these patients are given in Table 18. Accordingly, it has been recognized that the

Table 18 Changes of body weight following intravenous infusion of sesame oil emulsion into the patients, who underwent the antethoracic esophagogastrostomy after esophagectomy for esophageal cancer.

Days of exaination	Case 1 (47 years old)	Case 2 (58 years old)
Before operation	52.0kg	42.8kg
14th day after operation	51.5kg	37.0kg
* Before injection	45.5kg	30.0kg
5th day after injection	45.5kg	30.0kg
20th day after injection	46.5kg	31.0kg
40th day after injection	47.0kg	32.0kg **
60th day after injection	49.0kg	

* The value before injection is the value at the 23th day after surgical operation in the case 1, and the value at the 137th day after surgical operation in the case 2.
** This value is the one at 25th day after injection.

administration of the fat emulsion has a marked effect for the maintenance of body weight in such particular cases.[29)]

(iii) *Repeated administrations to healthy adults.*

Daily total of a mixture of 100cc of 20% sesame oil emulsion, 80cc of 20% glucose solution, 20mg each of vitamin B_1 and B_2 and 200 mg of vitamin C was given on halves every morning and evening. This procedure was repeated for 15

days, and the changes in nitrogen balance and the conditions of serum protein were examined. Even after repeated administrations, there was no sign of the abnormal increase of α-, β- and γ-globulin fractions in serum protein which is a natural outcome of stagnation of the serum lipid. The infused fat was quite smoothly metabolized. However, from the viewpoint of nitrogen balance no obvious nutritional effect could be recognized. Accordingly, its nutritional effect is obviously observed, from the viewpoint of economization of protein, only in patients in greater accelerated status of dissimilation.[11]

(iv) *Relationship between Serum Protein Components and Lipoprotein Components.*

In patients who underwent the gastrectomy in the diagnosis of gastric cancer, I examined the relationships between the serum protein components and the lipoprotein components before and after the surgical operation. A mixture of 80cc of 20% glucose solution, 20mg of vitamin B_1 and 200mg of vitamin C was given daily, divided into two portions, in the morning and evening, and a certain dose of blood was infused into these patients. 5% glucose solution, RINGER's solution and others were also administered subcutaneously for the definite duration. The mean value of the four cases under the equal condition was shown in Table 19.

Table 19 Relationships between paper electrophoretic fraction of serum lipoprotein and electrophoretic fraction of serum protein. (Each values show means of 8 samples)

Days of examination	Changes of serum protein					Changes of serum lipoprotein (%)		
	Conc. of protein (g/dl)	Electrophoretic fraction (%)						
		Alb.	α-Glob.	β-Glob.	γ-Glob.	α-lipoprotein	β-lipoprotein	0-lipoprotein
Before	7.0	53.98	10.42	14.24	21.36	——	——	——
2nd day after operation	6.9	54.08	9.34	13.23	23.24	− 5	−25	+ 6
3rd day after operation	7.1	50.16	11.24	17.24	21.36	+10	+10	+ 3
5th day after operation	7.2	47.62	12.10	18.22	22.04	− 8	+50	+20
7th day after operation	7.3	54.82	10.04	14.09	21.05	−20	+ 7	+ 5
10th day after operation	7.6	57.48	9.24	12.46	20.72	−10	−26	− 9
15th day after operation	7.6	55.16	11.29	13.41	20.14	− 2	+ 5	− 3

I compared the changes of the serum lipoprotein with those of serum phospholipids and neutral fats clarified by TATSUMI's[27] experiments in our labolatory. α- and β-lipoprotein in serum fluctuated in parallel with the changes of serum phospholipids

Table 20 Frequency of side effects.

Kind of infusion	Cases	Colloid shock	Back pain	Fever
Simple infusion	42	2 (4.76%)	0	1 (2.38%)
Continuous infusion	59	4 (6.88%)	1 (1.79%)	4 (6.79%)
Summary	101	6 (5.94%)	1 (0.99%)	5 (4.95%)

and choresterol. Serum *O*-lipoprotein fluctuated in parallel with the changes of neutral fats. The changes of α-, β- and *O*-lipoprotein in serum could also be respectively supposed to some extent by means of the estimation of α-, β- and γ-globulin fractions in serum. It was evident that the interpretation of electrophoretic patterns should be made not only from the viewpoint of protein metabolism, but also from that of the fat metabolism.[30] Their close relationship was well exhibited in the case of single infusion of fat emulsion.

IV. CONCLUSION

In present paper, we have demonstrated clinically that our sesame oil emulsion can certainly meet our expectations when it is applied with proper amounts of glucose and various vitamins.

The application of sesame oil emulsion reduced the consumption of tissue protein and helped the normalization of serum protein after surgical operation. Furthermore, with the simultaneous use of amino acid solution the infused fat was utilized solely as the source of calorie, so that, amino acids were used to rebuild the tissue protein and the restoration after surgical operation was greatly enhanced. Generally speaking, the economization of protein which the application of the fat emulsion affects, is the greater when the dissimilation in the metabolic process is the more remarkable. It should be also noted that a proper amount of vitamin B_1, vitamin B_2, vitamin C and glucose were administered simultaneously with the fat emulsion to make the injection effective. According to our experimental results, the infused fat globules are first phagocytized by the reticuloendothelial cells in the lung, liver and spleen. Then, after being changed to phospholipids from glycerides, they were discharged again into the blood stream and transported into the hepatic parenchymatous cells and the extrahepatic tissues.

During the histochemical studies described above, the phospholipids which were produced from glycerides in the alveolar phagocytes, KUPFFER's cells and splenic reticuloendothelial cells were well stained by SMITH-DIETRICH's, CIACCIO's and BAKER's staining methods. On the other hand, the phospholipids in the hepatic parenchymatous cells were well stained by SMITH-DIETRICH's and CIACCIO's staining methods which were not specific for the staining of phospholipid from the viewpoint of narrow definition, but could not be detected by BAKER's method which was specific for the staining of phospholipid. This raised the question, why was the difference in the staining characteristic exhibited? This was well accounted for by the following investigations. When the intravenonsly injected fat globules were discharged again into the blood stream after being changed to phospholipids from glycerides, α- and β-globulin fractions in serum protein increased in parallel with the increase of α- and β-lipoprotein in serum. When they began to decrease again, the ratio of saline soluble to insoluble protein in the liver rose, and $\alpha+\beta$-globulin fractions in the saline soluble liver protein markedly increased. At the same time, phospholipid content in the liver obviously increased. From the above facts, it was supposed that the phospholipids transformed from the infused fats were transported into the hepatic paren-

chymatous cells in the form of lipoprotein (combined form of phospholipid), not in the isolated form. This is applicable also to the case of its transportation to the extrahepatic tissues.

The metabolic process in vivo varies according to the kind of fatty acids to be contained in the fat emulsion. In the case of the fat emulsion containing highly unsaturated fatty acids in large quantities—cod liver oil emulsion for example—,phospholipid content and $\alpha+\beta$-globulin fractions in tissue protein increased only in the hepatic parenchymatous cells. On the contrary, in the case of sesame oil emulsion, which mostly consisted of higher fatty acids excepting the highly unsaturated ones, phospholipid content and $\alpha+\beta$-globulin fractions increased not only in the hepatic parenchymatous cells but also in the extrahepatic tissues, namely, muscles, kidneys and others.

From these facts it may be said that sesame oil emulsion is more suitable for the intravenous administration than cod liver oil emulsion. The former contains the higher fatty acids except highly unsaturated fatty acids, and the latter contains highly unsaturated fatty acids. Cod liver oil is a kind of fish oil, and easily gets auto-oxidation, forming harmful peroxide as the auto-oxidized product of the highly unsaturated fatty acids. The peroxides are accumulated in the liver and muscles and disturb the function of mitochondria in these tissues. They have destructive effect on the fermental system, and accordingly, disturb the fat metabolism. Therefore, a cod liver oil emulsion which does not contain any peroxide was made by estimating the peroxide value. However, there is the danger of a heavy accumulation of phospholipids in the hepatic parenchymatous cells in the case of repeated infusions of such emulsion. On the contrary, the sesame oil emulsion has no such defects. Even in the case of continuous administrations there is no fear of accumulation of phospholipids in the hepatic parenchymatous cells, and the phospholipids changed from glycerids were transported not only into the hepatic parenchymatous cells but also into the extrahepatic tissues and metabolized smoothly. The present studies proved its remarkable nutritional effects such as economization of protein, improvement of electrophoretic pattern of serum protein and the maintenance of body weight.

In present paper, it has also been clarified that the electrophoretic fractions of serum protein, the paper electrophoregram of serum lipoprotein and the concentration of the serum lipids have a close interrelationship between each other.

V. SUMMARY

The process of fat metabolism in vivo was studied with a fat emulsion which was produced in our laboratory. The present studies also proved its remarkable nutritional effects with clinical application. The following summary was obtained:—

(1) The fat globules infused intravenously are phagocytized by the reticuloendothelial cells, and after being changed into phospholipids, they are discharged into the blood stream again. These phospholipids are transfered into the hepatic parenchymatous cells and other organs not in the free form but in the combined

form, that is, as lipoprotein.

(2) In order to interpret the electrophoretic pattern, the phases not only of protein metabolism but also of fat metabolism must be taken into account.

(3) The fat emulsion prepared in our laboratory seldom caused harmful side effects, when it was applied according to the above described methods to prevent colloid shock. The administration of sesame oil emulsion was remarkably effective in economizing protein and maintaining the body weight.

(4) In case of the simultaneous administration of amino acid solution with fat emulsion, the amino acids were utilized for the rebuilding of the tissue and serum protein, and were not exhausted as the source of calories. Accordingly, a more obvious improvement of the electrophoretic pattern of the serum protein was recognized.

(5) The phospholipids which consist of highly unsaturated fatty acids were chiefly transported into the hepatic parenchymatous cells in the form of lipoprotein, while, the other hand, the phospholipids which are composed of the higher fatty acids excepting the highly unsaturated fatty acids could be transported not only into the hepatic parenchymatous cells but also into the extrahepatic tissues. In this regard at least, such fat as sesame oil which is made only of the higher fatty acids except the highly unsaturated fatty acids is most suitable as the material for the fat emulsion. Kinds of fat such as cod liver oil which contains the highly unsaturated fatty acids in large quantities, are quite dangerous, because highly unsaturated fatty acids have a tendency to be auto-oxidized to peroxide. The peroxides accumulate in the liver and muscles and disturb the functions of the fermental system.

(6) Even in the case of serial administration of the sesame oil emulsion in our laboratory, no tendency of stagnation of serum lipids could be recognized, and it was supposed that the fat emulsion infused intravenously was transformed and utilized smoothly. So far as the electrocardiographic studies were concerned, the emulsion did not show any danger of aggravating arteriosclerosis at all.

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*Classification of reference

1)……5) Reports of the intravenous administration of fat

6)……19) Studies on protein metabolism

20)……34) Studies on the intravenous infusion of fat emulsion in our laboratory

35)……49) Studies on fat metabolism and electrophoresis

50)……56) Clinical studies on nutrition before and after operation

和 文 抄 録

経静脈性脂肪輸入の栄養学的効果に関する臨床的研究

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我々の作製した脂肪乳剤の生体静脈内注入時の体内代謝過程の一部を蛋白代謝の面から考究すると共に，之が人体応用時の栄養学的効果についても検討，次の様な結論に到達した．

(1) 静脈内へ注入された脂肪球は肺，肝，脾等の網内系細胞群によつて摂取され，それら細胞内で glyceride から phospholipid に変じた後，再び流血中に放出されるが，斯る phspholipid は決して遊離形のまゝで，肝実質細胞内及び肝外組織中へ移行するものでなく，常に lipoprotein なる結合形態となり，それらの臓器組織内へ移行し得るものと思われる．

(2) 血清蛋白分屑像を解釈するにあたつては，必ず生体内脂肪代謝の様相をも充分に考慮に入れた解釈がなさるべきもので，従来の如くただ単に蛋白代謝の面のみから考察されるべきものでない．

(3) 我々の作製したゴマ油乳剤の臨床的応用に際しては，常に colloid shock の発生防止対策を構じた注入方法が採用される限り，その副作用の発現頻度は極めて少ない．而してそれは経口的栄養摂取が不充分で且つ生体内代謝の様相が異化的方向に傾いているものに対しては著明な蛋白節約作用を招来し，ひいては体重の維持にも有効に作用する．

(4) 本脂肪乳剤の静脈内注入に当り，アミノ酸製剤をも併用する時は，アミノ酸はその本来の使命である組織蛋に血清蛋白の再建により有効に使用せられ，之が熱源として消費されてしまうことが極力抑制され，その結果ゴマ油乳剤の単独注入時に較べ，血清蛋白分屑像の改善はより一段と促進される．

(5) 高度不飽和脂肪酸は，phospholipid として，それも常に phospholipid は lipoprotein なる結合形態で専ら肝実質細胞内に移行処理されるに反し，高度不飽和脂肪酸以外の高級脂肪酸は同様の過程を経て

肝臓実質細胞内のみならず，筋肉，腎臓等の如き所謂肝外組織中へも直接移行し得て円滑に処理される．従つてこのような生体内脂肪代謝の様相から考えても，低級脂肪酸，あるいは高度の不飽和脂肪酸以外の高級脂肪酸のみからなるゴマ油の如き脂肪体を脂肪乳剤の原料として使用することが望ましい．又高度不飽和脂肪酸の自働酸化にあつて生ずる過酸化物は肝臓，筋肉中にも蓄積し，生体に対し極めて障碍的に作用するから，斯る観点からしてもこのような危険性の多い高度不飽和脂肪酸を多量に含有する肝油の如きものをその原料とすることは決して望ましいものとはいい得ない．

(6) 我々のゴマ油乳剤はそれを連日に亘り人体静脈内へ反覆注入しても，血清蛋白分屑像，竝に血清 lipoprotein の消長等からみて，決して血中に停滞する傾向は認められず，生体内で円滑に処理利用せられているものと考えられる．